Selecting Capacitors

Capacitors are a common passive device in our circuits, but they can be difficult to physically manufacture in real life. We learned during filter design that we only could produce a limited range of values for use in our circuits. What we did not elaborate on is that the upper limit of this range could be exceeded **if** we can restrict the DC voltage across the capacitor to a single polarity. We will see that the selection of real-world capacitors is thus divided roughly into categories:

1. **Non-polarized capacitors** – Typical characteristics of this capacitor type are (i) low capacitance value (up to $\sim 1 - 10\mu F$), (ii) high working voltage (if needed), (iii) small to moderate size, and (iv) better tolerance ranges.
2. **Polarized capacitors** – Typical characteristics include (i) large capacitance (from $\sim 1 - 10\mu F$ up to $10 - 100mF$ for regular electrolytic types), (ii) limited/low working voltage (up to $\sim 50 - 63V$ most common), (iii) poor tolerance ($-20/+80\%$ is common), (iv) large size, and (v) **one polarity only** for DC.

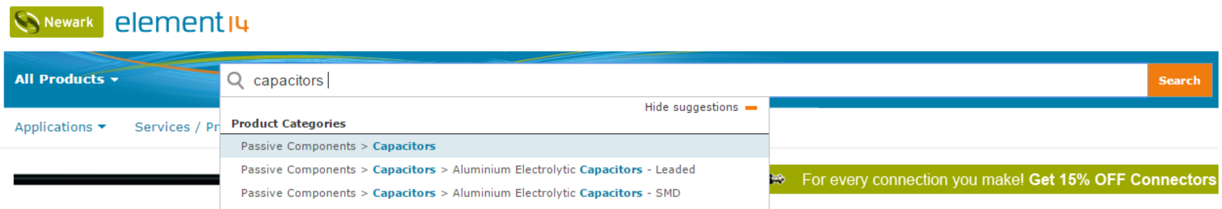
There are other subtleties to capacitor selection depending on the specific application, but the above criteria will be more than enough to develop a basic selection process. In fact, we will basically use only capacitance and voltage as our main criteria here. As before, we will continue an example from the class notes to explain the selection process. Recall again the full-wave example on p. 165 of the notes. The relevant information is copied below:

Desired Output Specifications
$V_{R_{Peak-Peak}} = 20\ mV$
$V_{Cap_{Peak}} = 12\ V$ (rectifier output/regulator input)
$C \geq 4170\ \mu F$

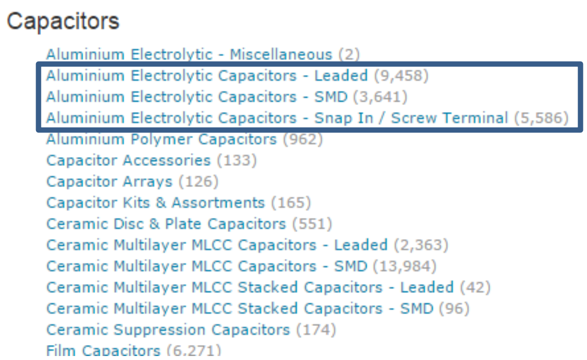
In the example, it was decided the capacitor needed to be at least 4170 μF to meet the ripple requirements. At the same time, we know that the capacitor may be charged to a voltage as high as 13 V at the peak of the output waveform of the rectifier.

Large Capacitor Selection Process

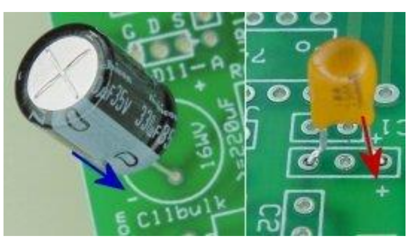
1. The capacitor value will be our indicator as to the sub-type of capacitor we need; for this large capacitance a polarized capacitor will likely be needed. The **aluminum electrolytic** capacitor is the most common polarized type by far. So, to begin our selection go to your favourite manufacturer or distributor website and navigate to the section for capacitors. For this example, I will use Newark (http://canada.newark.com/), a large electronics distributor. You can search for capacitors using Digikey or other sources, as well.



2. We select one of the ‘Aluminum Electrolytic Capacitors’ categories:



Note that the three sub-options refer to the way the capacitors are **mounted**. The ‘leaded’ category refers to capacitors with wire leads, suitable for through-hole mounting. SMD refers to smaller surface-mount capacitors. Lastly, snap-in and screw-terminal types are reserved for exceptionally large capacitors – high voltage, capacitance, or both.

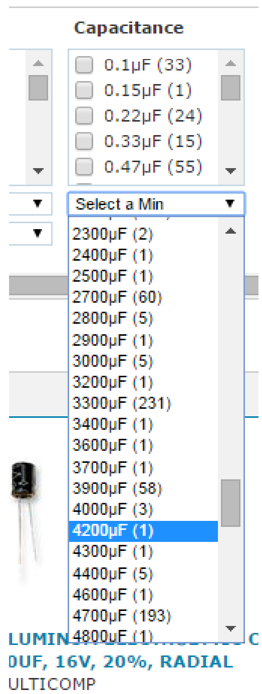


Through-Hole

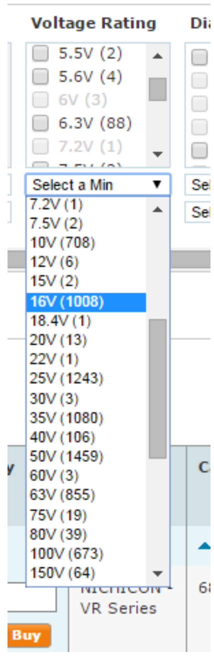
Surface Mount

Screw Terminal

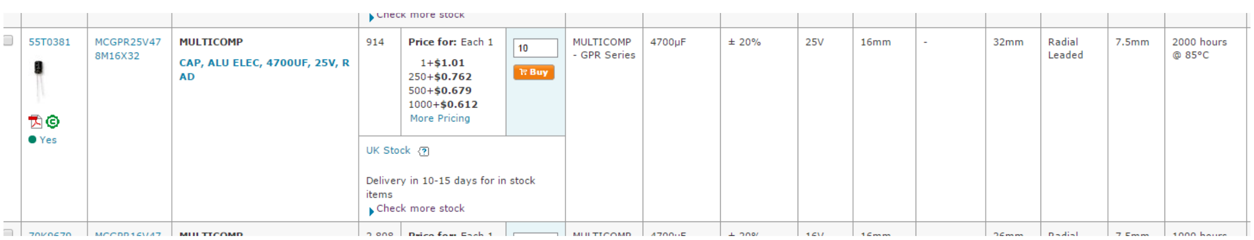
3. Selecting the ‘leaded’ type (has the most and cheapest options), we are again given the option to filter the selection by different parameters. To begin, we select a range of capacitances that satisfy our criteria of $C \geq 4170\mu F$.



4. While capacitance is the primary factor in selection, we must also choose an appropriate **working voltage**. When a capacitor is charged to a certain **DC** level, the insulating materials that make up the capacitor must resist breaking down and conducting. Electrolytic capacitors generally have lower voltage ratings available than non-polarized types due to their physical construction. While there is a desire to select the lowest voltage possible (due to cost/size), we should be careful and allow a **safety margin** on this parameter. If a capacitor is charged over its rated voltage, it can quickly fail. And, in a linear power supply such as this one, it is possible for the voltage at the capacitor to vary greatly. The transformer (which supplies the rectifier and charges the capacitor) is rated at **loaded** output. This means that if we select a transformer that provides a peak voltage of around $12\,V$ after the rectifier, this figure is valid at **maximum** load. The transformer output can rise by a significant margin when lightly loaded, meaning our capacitor could be charged much higher than $12\,V$ when the power supply is lightly loaded. Generally, a safety margin of $25-50\%$ is sufficient when selecting working voltage. For this example, we select capacitors with working voltage $16\,V$ and up, giving at least a 33% safety margin.



5. We can now sort by our secondary requirements (cost, size, etc.) and select the final capacitor. You may also want to select 'In Stock' to filter out most of the uncommon, highly specialized capacitors. For example, the following was the first in-stock result when sorting by cost:



You may notice that there are multiple options available for any given combination of capacitance and voltage. Some may be more expensive but smaller in size, or cheaper but larger. There are also other parameters such as temperature ranges, expected lifespan, and tolerance which affect cost. For this assignment, selecting by capacitance and voltage is sufficient.

Small Capacitor Selection Process

If the capacitance you need is small, you should select a more appropriate type of **non-polarized** capacitor. The steps are otherwise relatively similar:

1. When selecting the category of capacitor, select one of ‘Ceramic Disc & Plate,’ ‘Film Capacitors,’ or ‘Silver Mica Capacitors’. These are the most common types of non-polarized capacitors. While they each have some unique properties, these properties will not affect our selection in this assignment. If in doubt, start with the largest category.
2. Select capacitance first; you will notice that most capacitors available have capacitance less than $\sim 1 - 10 \mu F$.
3. Working voltage is generally less of an issue for small capacitors. You may notice that the majority of capacitance selections do not even have any capacitors with working voltage below $\sim 50\ V$. And, since these smaller capacitors are more commonly used in applications like our active filters, voltages tend to be low anyway.
4. Complete your selection by sorting for cost, size, etc. as needed.